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FORM OF SEEDS AS A FACTOR IN NATURAL SELECTION IN PLANTS.

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THE present aspect of the fields in the immediate neighborhood of the south grounds of the University of California, at Berkeley, when compared with their general appearance five years ago, when the flora of the locality was first noticed by me, exhibits a marked contrast; and though during this time the varying character of the vegetation from year to year attracted my attention, the altered physiognomy of the fields particularly impressed me this past season, and curiosity has led me to seek for the causes which have produced what may be regarded as a most striking change.

The complexity of questions of this kind is increased, not only through the simpler factors involved, some of which are given below, but by the sequence of relationship of such factors to each other, which it is difficult to detect.

The climatology of the seasons during which such changes have been progressing;—the tillage of proximate lands, and the introduction of new plants, or of plants new to a locality, through this agency or by other artificial means more or less direct, which follow the settlement of a region;—other changes which follow through neglect of tillage, as where the cultivation of farming lands is abandoned, as is generally the case where such lands are divided and cut into small parcels for village or town plats or lots;—these are a few of the more conspicuous agencies which produce changes of the kind mentioned herein, in the local flora of such neighborhoods. Again, the time required for the growth

of a plant, from the sprouting of the seed to maturity, differs greatly in different plants, and the seeds of some plants germinate in much less time than the seeds of others. From this cause the aspect of the fields changes during the same season; those plants whose seeds start quickly and attain maturity in the shortest time, dominate for awhile and give one aspect to the fields in the first part of the season, and those plants whose seeds sprout slowly only reach maturity after the earlier have passed their prime or died, then dominate[1] and later in the season give to the fields a a different complexion or appearance.

The occurrence of these changes and the domination of this or that plant inside of or within the number of plants which form the flora of a certain region, may be conspicuously modified, in one year or season as compared with another, by the character of the season as previously referred to. As some plants thrive best with only a moderate supply of moisture, and are dwarfed, decreased in number of individuals or suppressed by the "drowning" of the seeds as the farmers call it, through excess of "wet" —so the latter might be highly favorable to the germination of the seeds and earlier development of the plants of some other species, which in normal or ordinary seasons would appear much later.[2]

The effect of only one such season might extend through several seasons, and materially modify the landscape features in its annual plants for a period of many years.

Without further enlarging in this direction on certain points which have been referred to, as they cannot properly be passed unnoticed, attention is called to another class of factors, not generally recognized, but of sufficient importance not to admit of exclusion, wherein natural selection is illustrated as performing its part in a different way.

The domination of "the fittest," the character of a season con-

[1] Thus *Madia sativa*, popularly or unpopularly known as "tar-weed," and obnoxious to pedestrians on account of its gummy exudation which injures clothing, though inconspicuous in early summer, later in the season becomes a prominent plant.

[2] In considering this point the frequently recurring discussion of what may be entitled "Cheat *vs.* Wheat," is brought to mind; some farmers contending that in seasons of unusual "wet" the wheat turns to cheat; others that the cheat, which in ordinary seasons is kept back, suppressed by the wheat (which makes the earliest start and quickest after growth, therefore maturing first), in unusually wet seasons gets the start of the wheat and dominates the field for that season. (Cheat is the local or vulgar name for *Lolium temulentum*.)

sidered, has been inferentially if not directly shown, where the effect of an unusually wet season is referred to; so certain plants which now dominate in my immediate neighborhood illustrate how natural selection has assisted, to say the least, in producing the change in the open fields near my residence in Berkeley, through the advantage which one form of seed has over seeds of a different form. And this aside from its interest to the scientific observer, is of special interest to the farmer, for it enters into the economics of his business, as may be seen further on.

Only a few years ago the entire region hereabout, from the hills to the shore of the bay, was either farmed or used for pasturage. Where not tilled, over large portions of this area, the wild mustard (*Brassica nigra*) abounded, and was regarded by the farmers as a pest; it grew and thrived nearly everywhere, and often attained a height sufficient "to hide all of a standing horse but his head." During later years the mustard has surrendered a part of the field to an (introduced?) turnip and radish, plants of the same order, with smooth seeds, and all three of these have been giving way, gradually yielding to other plants, native and introduced.

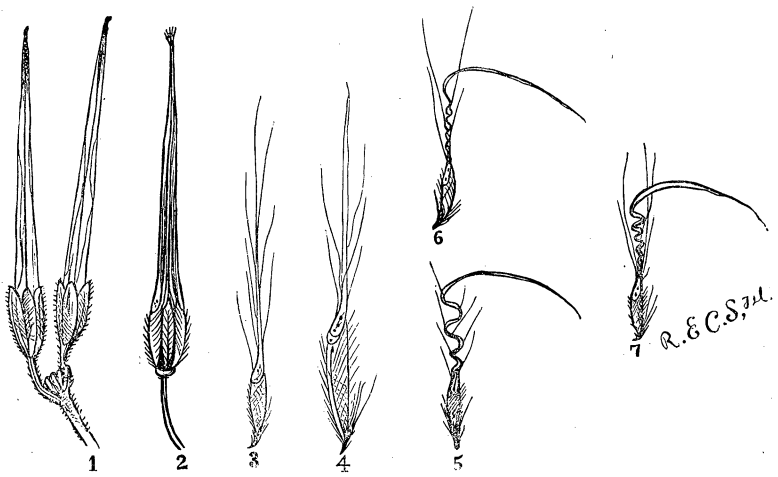
The mustard may, in some localities, regain in part its lost supremacy, through the assistance of man, as the seed within a few years has become of economic importance, and is now prepared for culinary purposes, and is also on the list of products in the export trade of the State.[1]

The principal plants within the more limited area first mentioned in this paper, to which these smooth-seeded *Cruciferæ* have been gradually yielding, have seeds of a different form. One of these is the *Alfillarilla*, or "filaree," by which name it is more generally known, a plant which is closely related to the geraniums, if we may judge from analogies of form in leaf and flower, structure of seed receptacle and shape of seeds. This alfillarilla, as it is called by the Spanish Californians, is an *Erodium*, and two species grow here, namely, *E. cicutarium* and *E. moschatum*.[2]

[1] In 1875, 1013 centals, valued at $4849; 1876, 5458 centals, valued at $18,314; 1877, 5065 centals, valued at $15,412, and in 1878, 7552 centals, valued at $21,689, were exported to foreign countries, making a total for the four years of 19,088 centals of the value of $60,264.

[2] Cattle eat these readily and appear to be fond of them, but the latter species especially is not a desirable plant for milch cows, as it gives a disagreeable odor and taste to the milk.

This genus is a form of "cranesbill," and as will be seen by Fig. 1, and its gynæcium, Fig. 2, is somewhat like that of *Geranium maculatum*, as figured in Gray.



Crane's bill (Erodium) or Alfillarilla. From nature.

The latter figure, with the sepals removed, shows the ovaries with their slender bearded[1] styles or awns (Figs. 3 and 4 enlarged) *in situ*, cohering to the elongated axis of the receptacle.

It will be observed upon examination that the ovaries are in fact a barb-shaped sheath enclosing the seed, the surface of which is covered with short stiff hairs or small bristle-like spines visible to the unaided eye, but of course more conspicuous through a common lens. The tip of the barb is also peculiarly pointed and curved; produced from the upper end of the ovary (that opposite to the tip) is a thread-like process or style an inch or more in length, varying in different specimens, so that the ovary as a whole may be compared to a tiny arrow, which it much resembles.

Now if we examine an unripe specimen before the sepals have separated from it (Fig. 1), we shall find four to five of these miniature arrows (carpels) side by side, closely fitting together, being snugly packed around the prolonged central axis of the gynæcium, the base of which is sufficiently expanded or swollen to receive the tips.

After the blossom has withered and the ripening process

[1] It is presumable that the Spanish name *Alfillarilla* was suggested by these delicate filaments.

advances, it will be found that the arrows (ovaries) in these little bundles, or quivers, if it be allowable to so name them, exhibit a tendency to separate from the central stalk or axis of the receptacle, first curling upwards and finally falling off, or are blown out and distributed by the wind.

As soon as the ovaries are detached as above, their styles commence twisting (see Figs. 5, 6 and 7), and the delicate threads, as seen upon and along the slender shaft or style, are consequently thrown out at increased angle (sometimes at a nearly right angle), so that the entire ovary now presents somewhat the appearance of the skeleton or frame, as it were, of a parachute, which after a breeze has passed and the air is calm, causes it to descend vertically, barb downward, so that the tip first touches the ground; the end of the tip is also barbed, so that if the soil at the spot where it alights is at all loose, it holds on. If the weather is dry the style or awn becomes still dryer, which causes it to twist still more, and the torsion caused by increased desiccation, turns it deeper and deeper; while if the atmosphere becomes damp or a rain occurs sufficient to moisten the slender style, though but little moisture is required to relax the torsion, the bite or grip previously made is not lost, because with the softening of the style the barb or ovary is not twisted out; whatever hold has been gained is retained, and the torsion renewed with recurring desiccation, and so the process of planting goes on.

The small bristles on the surface of the ovary or sheath are set obliquely upwards to the axial length and assist in the process of planting. It will be seen that every alternation of atmospheric conditions, characterized by positive moisture or dryness, assists in the operation.[1]

The luxuriant growth of the cultivated geraniums in California is well known. In and around Berkeley nearly every yard has many plants of one or more varieties. On my premises are numerous vigorous plants of large size and of many varieties, including Pelargoniums.

[1] This is easily illustrated by the following simple experiment: Take a tumbler and fill it with sand; select specimens of the gynæcia or receptacles which are beginning to turn brown or approaching ripeness, that is while the seeds complete with barb and shaft are straight; place the barb sufficiently deep into the sand so that its tip is fairly set; it will soon be noticed as the ripening progresses, or as the awn or shaft begins to dry that it also begins to curl or twist, and that in curling it buries the barbed ovary deeper and deeper, as turning a corkscrew carries the same deeper and deeper into a cork.

The question naturally occurred, why have not these ornamental forms which have the great advantage over their wild relatives of the protection and fostering care of man, spread like the unprotected *Erodium* and divided the field with it or driven it out? The seeds are not infertile, for under the shade of the sturdy plants which produce them, protected during the hot dry summers by the leaves which fall from the parent plant and make the thin mulch which covers them, with infrequent and slight sprinkling during the long rainless season, hundreds of young plants may be seen in the fall which have sprung from the loose and slightly moistened soil and acquired their second pair of leaves. The carpels are of the same form as those in *Erodium;* few persons could detect any difference, and the awn or style twist in the same way. Upon critical examination, however, it was found that the tip (insertion point) of the carpel was covered with *soft silken hairs instead of rigid bristles,* too soft to act as barbs, and the insertion point is neither as sharp or stiff nor curved the same as in Erodium.

The seeds of all of these foreign forms which have been examined by me in this connection, are apparently dependent for distribution chiefly on the winds, for the delicate filaments along the style if not longer are more numerous than in Erodium, so that when the twist or torsion has occurred, they present a form well adapted for distribution by flight.

Darwin has noticed the advantage which winged seeds have in this respect, as well as those plants whose seed cups or receptacles have a rough exterior, which get caught in the hair or fleece of animals and are thereby transported from place to place. In this way also the seeds of the geraniums have some advantage, but as compared with those of Erodium, so far as planting by natural methods is considered, the advantage is conspicuously in favor of the latter.

I do not know how it is with the cultivated varieties referred to in their native country, neither can I assert how it might be with our Erodium forms if transplanted to another region; a different environment might induce a gradual modification in those peculiarities which in the environment of Berkeley are important factors in their propagation and the extension of their geographical domain. It is not difficult for a person who is familiar with the cultivation of plants, and who has had an experience covering

widely separated regions with different soils and climates to conceive of conditions which might give to Erodium a rank succulent and tender growth, which, continued for a few years might differentiate the rigid bristles and barb of its ovaries in the direction of greater flexibility; or on the other hand to modify the soft nap or pile on the surface of the ovaries as well as the flexible tip of the foreign geraniums in the direction of rigidity or spine-like stiffness. Those influences which induce succulent or ligneous tendencies in plants are to a great extent the factors in such variation.

The seeds of geraniums found in the highlands of Uruguay, as well as the seeds of certain other plants, exhibit the same interesting peculiarities.[1]

Notwithstanding the browsing of cattle the Erodium gained upon the previously conspicuous forms. Within the past two years, however, it has been losing ground, in some places more

[1] An exceedingly brief outline of this paper was read by me before the California Academy of Sciences, June 17th, 1878; subsequently my friend, Mr. X. Y. Clark, sent me the following clipping from *Nature* of March 1, 1877, which I had not previously seen:

"*Hygroscopic Seeds.*—I have lately received an interesting letter from Fritz Müller, in St. Caterina, Brazil, on the subject of hygroscopic seeds. He tells me that in the highlands of the Uruguay he has succeeded in discovering more than a dozen grasses, as well as a species of geranium, whose awns are capable of hygroscopic torsion. He has been so kind as to send me specimens of the grass-seeds, and many of them appear to be as beautifully adapted as those of Stipa, Avena, &c., for penetrating the ground in the manner which I have elsewhere described (Trans. Linn. Soc., vol. 1, part 3, p. 149, 1876). The most curious among the specimens received are the seeds belonging to the genus Aristida. In one of these the awn is longitudinally divided into three fine tails, six or eight inches in length, each of which twists on its own axis when the seed is dried. These tails project in three directions and more or less at right angles to the axis of the seed, and Fritz Müller states that they serve to hold it in an upright position with its lower end resting on the ground. The seed is pointed and barbed in the usual manner, and when it is made to rotate by the twisting of the awns, it evidently forms a most effectual boring-instrument, for Fritz Müller found many seeds which had penetrated the hard soil in which the parent plant was growing. Another species of Aristida is interesting to me, because it illustrates the explanation which I gave of the torsion of the awn of Stipa, namely, that each individual cell of which the awn is composed is capable of torsion, and their combined action results in the twisting of the whole awn. Now in this species of Aristida each of the three tails into which the awn is divided is capable of torsion on its own axis, and as the seed dries they twist up into a perfect three-stranded rope, just as the component cells combine to produce the rope-like twist of the Stipa awn. And as the tails wind together and form the strands, the seed is made to rotate and thus bury itself in the ground.

"Down, Beckenham, February 19. FRANCIS DARWIN."

The Transactions referred to in Mr. Darwin's foot-note are not within my reach, and the article referred to by him, is unknown to me. I am curious to learn how far my observations and comments, made quite independently and without knowledge of anything elsewhere written, may agree with or sustain previous writers, or be corroborated and sustained by their observations.

rapidly than in others, through the conquering advance of another plant, a form which, being not only worthless as food but repugnant to cattle, is not molested by them in its onward march for supremacy, which over large areas it has already achieved, to the nearly total exclusion of Erodium.

This latter is what is known as barley-grass, or false barley, *Hordeum maritimum*, of which a spikelet is shown in the following figure (8).

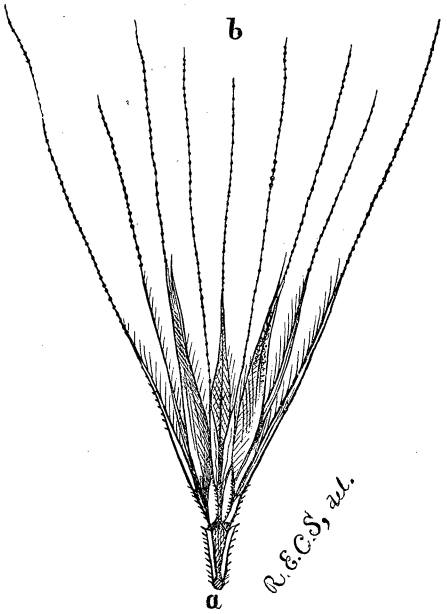


FIG. 8. Spikelet of Darley Grass.

Upon a careful examination it will be seen that the entire spikelet throughout is closely set either with short rigid bristles (as on the glumes and palea) or with minute sharply-pointed barbs as exhibited in the awns throughout their entire length, and on the edges of the arrow-shaped base or stem (insertion point) of the spikelet. Upon the long bristle-like awns these barbs are closely set, but are so very small as not to be at first detected; on pulling one of them through the fingers in a direction from the tip *a* towards the extremity of the awn *b*, no difficulty is encountered, it may be done with ease; but on pulling it in the opposite direction, namely, from *b* towards *a*, resistance ensues from the multitude of minute barbs, and the effort, if persisted in, results in the breaking of the awn.

The spikelet as a whole may be regarded as a wonderfully ingenious, compound and effective barb, having through the angle of its various parts and the length of the awns, all of the advantages of the parachute form which Erodium and the cultivated geraniums referred to derive from their twisted styles with fine lateral hairs, for floating in the air *and for poise in ultimate descent.*

The principal advantage which Erodium has over this Hordeum is in the hygroscopic torsion of the styles[1] or awns; this is more than balanced by the preponderance of barbs and bristles in Hordeum, all of which are set at some angle outward and upward, while the spoon-shaped basal nib, arrow-head or insertion point, whichever it may be termed, is perhaps equally well adapted as the same part in the carpels of Erodium, for biting and holding on; once inserted, every motion it receives, whether from the wind or other source only inserts it deeper and deeper, and in this the nib or insertion point is assisted by the other parts of the spikelet. Another and probably the chief advantage which the barley-grass has over Erodium is in the greater number of seeds (three in a spikelet) in a single plant; recurring again to the fact that cattle dislike it on account of its wiry, prickly character, which gives it almost perfect immunity or protection from their browsing, it is easy to perceive why it has become nearly if not quite "master of the situation."

To the farmer it is a pest and to the pedestrian a nuisance, as the spikelets stick into the trowsers around the foot, working in deeper and deeper with every motion, often crawling upwards as far as the top of the boot-leg, where if the stocking is long and extends above, it catches and follows down into the foot, irritating the flesh and compelling a halt in order to remove the annoyance.

Under a microscope lens the main barb (insertion point or nib) is an interesting and curious object; the unshaded edges (see figure) and the tiny barbs upon the same are translucent, being

[1] "A wild oat * * * * * the *A. sterilis* of botanists, is remarkable for the hygrometric properties of the seed. Two grains usually grow together, and they have a stout, bent and twisted awn. When the oat is ripe it falls out of its glume, and in warm dry weather may be seen rolling and turning about on its long ungainly legs as they twist up in consequence of their hygrometric quality. They turn and tumble about till their awns are so twisted that they can twist no further. They then remain quiet till the dew falls, or they are moistened by a shower, when they rapidly untwist and run about as if anxious to escape from the wet."—*Baird's Dict. Nat. Hist. p.* 27.

nearly pure silica; so also are the minute barbs upon the awns; and the short bristles on the surface of the ovaries in Erodium resemble, in miniature, the spiny bones in the dorsal fin of a perch.

Other bearded or barbed-seeded or rough-burred plants have increased in several places within the region referred to in this paper, among these are the burr-clover (*Medicago denticulata*) and the thistles (*Centaurea melitensis* L., and *C. solstialis* L.), both introduced species; the barley-grass, however, has the advantage over all others and is likely to maintain it.

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A SPECULATION ON PROTOPLASM.

BY PERSIFOR FRAZER, JR.

THE researches of comparative anatomists in late years have thrown much light upon the mode of development of the germ or embryo to the adult form of the species from which it is derived, and by the labors of Haeckel, Huxley, Cope, and others, much encouragement has been offered to the hope that man will yet push his knowledge of the processes of the development of life at least so far into their infinitesimal beginnings that the highest powers of the microscope and the most delicate appliances of physical science can no longer aid him. In this gradual triumph over what at first seemed insurmountable difficulties, many lines of interesting speculation are opened up, which, though lacking the permanent value of demonstration, are not without a certain use.

One of these is connected with the material out of which these wonderful structures are built; a material seeming to form the common point of intersection of all lines of organisms. For the latter, though widely separated in their several states of perfect development, when traced towards their origin, exhibit more and more striking resemblances and analogies; and they consist of a common substance, namely, the ultimately structureless (or amorphous as it is sometimes perhaps too hastily called) protoplasm or sarcode.